REMARKS:

Applicant has cancelled claims 13-20 per the Examiner's Restriction/Election requirement in his Office Action of August 21, 2006. Applicant has also added new claims 21-28. Applicant believes that no new subject matter has been introduced.

Summary of Telephone Interview

Applicant wishes to thank Examiner Wilkins for his courteous telephone conference on November 22, 2006. First, Applicant pointed out to the Examiner that Tzanavaras et al does not teach or suggest that any wetting problem exists and, to the contrary, it asserts (at col. 3, lines 13-22) full agitation (and implied wetting) inside even the smallest opening. Second, Applicant pointed out that Downes et al teaches that: (a) a wetting problem (i.e., a lack of wetting) is most prevalent for narrower, higher aspect ratio holes or vias, and (b) wider, lower aspect ratio holes or vias have less of a wetting problem. Third, Applicant pointed out that the current patent application (contrary to the teaching of Downes et al.) discovered that the wetting problem is more prevalent in wider, lower aspect ratio openings than in narrower, higher aspect ratio openings. Fourth, Applicant pointed out that claims 4-6, 9, and 11-12 require that the wetting or activation solution used during the ultrasonic or megasonic step, be the same as the electrolyte used for the jets electroplating step, and that Downes et al teaches away (at paragraph [0040]) from these claims by requiring a separate wetting solution from the electroless solution. Fifth, Applicant pointed out that claims 7-12 require a metallic surface on at least the sidewalls (of the openings) and the field, whereas: (a) Tzanavaras et al discloses plating through a photoresist mask where only the bottom of the openings comprise a metallic surface; and (b) Downes et al. discloses drilled holes or vias in (insulating) printed circuit boards, with insulating sidewalls surfaces.

In response to Applicant contentions, the Examiner encouraged Applicant to attach a Declaration (or Affidavit) to his Amendment. Per the Examiner's suggestion, Applicant has attached below a Declaration under 37 CFR 1.132.

Arguments

I. The Examiner rejected claim 1 under 35 U.S.C. 103(a) as being unpatentable over Tzanavaras et al (US 5,421,987) in view of Downes, Jr et al (US 2002/0189637). The Examiner stated that:

> Tzanavaras et al teach (see figure 1) a method for electrofilling a metal or alloy inside at least one opening located in a front surface of a substrate, the front surface of the substrate including at least one opening and a top field surrounding the opening, wherein the opening included a bottom and sidewalls coated with an exposed metallic surface, wherein the steps of the method included immersing the substrate in an activation solution (electrolyte), applying high pressure electrolyte jets to the substrate, wherein the electrolyte included metallic ions of the metal to be plated and applying an electroplating current to the substrate to electroplate the metal inside the opening.
>
> Thus, Tzanavaras et al fail to teach applying ultrasonic or megasonic vibrations to the substrate prior to the onset of electroplating.
>
> Downes, Jr et al teach (see abstract and paragraphs 22, 30 and 39-41) applying ultrasonic vibrations to a liquid to ensure adequate wetting of small vias or holes with

Therefore, it would have been obvious to one of ordinary skill in the art to have added a step of applying ultrasonic vibrations to the substrate and electrolyte as taught by Downes, Jr et al to the method of Tzanavaras et al because the ultrasonic vibrations would have increased wetting of the small vias and holes present on the substrates of Tzanavaras et al.

Claim 1 is Not Obvious:

No Motivation to Combine

Applicant respectfully submits that Claim 1 is not obvious over Tzanavaras et al in view of Downes et al because there is no teaching, suggestion, or motivation whatsoever in Tzanavaras et al or in Downes et al to combine the references. In particular, the Examiner asserts that the motivation for one of ordinary skill in the art to combine the references is: " ... applying ultrasonic vibrations to the substrate and electrolyte as taught by Downes, Jr et al to the method of Tzanavaras et al because the ultrasonic vibrations would have increased wetting of the small vias and holes present on the substrates of Tzanavaras et al."

Applicant respectfully submits that the Examiner is wrong since Tzanavaras et al states (at column 3, lines 13-22): "The impinging powerful jets create turbulent flow at the substrate's surface, thus providing efficient agitation and replenishment in all areas, including complex mask features with varying depth and opening sizes. High aspect ratio opening areas receive a similar degree of agitation (and replenishment) as areas of lower aspect ratios. Even features with the deepest and smallest openings (having the highest aspect ratio) receive essentially the same degree of agitation as areas of lower aspect ratios."

Thus, as one can appreciate from this, one of ordinary skill in the art, reading Tzanavaras at al., would not understand that any wetting problems exist inside small or high aspect ratio openings. To the contrary, one or ordinary skill in the art would understand that the jets facilitate good agitation (and wetting) inside even the deepest and smallest openings (having the highest aspect ratios). In addition, because Tzanavaras et al. teaches that the jets alone accomplish good agitation (and hence wetting) inside the low and high aspect ratio openings, that person of ordinary skill in the art would understand that using any extra means (such as ultrasonic) to increase wetting would be superfluous, and would unnecessarily increase the number of processing steps, complexity, and cost. Because of this, in fact, Tzanavaras et al. teaches away from using extra means (such as ultrasonic) to increase wetting. Therefore, Applicant respectfully submits that the combination of Tzanavaras et al with Downes et al is improper, since neither one of these references suggests or provides any motivation to combine the references in the manner suggested by the Examiner, and since Tzanavaras et al teaches away

from Downes et al. For at least this reason, Applicant respectfully submits that Claim 1 is not obvious over Tzanavaras et al in view of Downes et al.

Suprising and Unexpected Results

Furthermore, Applicant respectfully submits that Applicant surprisingly and unexpectedly discovered that wetting problems are mostly prevalent inside relatively wide and low aspect ratio openings (see attached Applicant's Declaration), contrary to the teaching of Downes et al that wetting problems are most prevalent in narrower and higher aspect ratio drilled holes or vias in the printed circuit board panels. For example, Downes et al states:

> (a) (at paragraph [0005]) "[a]lthough potentially for small diameter holes or vias with small aspect ratios, agitation in a fully degassed tank (without ultrasonic energy) may be sufficient to dissolve and eliminate all of the air bubbles which are present in the bath or liquid."; (b) (at paragraph [0023]) "[w]herein maintaining the degassed condition of the liquid in the tank is actually of greater significance than a direct application of ultrasonic energy to the panels."; (c) (at paragraph [0024]) "Although so-called panel bumping and panel tilting have been employed in the technology in order to remove air from drilled holes prior to and/or during the plating processes, this maybe somewhat effective for larger-sized holes or vias, but remains essentially ineffective for smaller holes or vias, particularly those possessing high-aspect ratios."; and (d) (at paragraph [0042]) "In the event that the holes are small diameter sized with only small aspect ratios, rather than employing the ultrasonic sender array 26 in the prewetting tank 24, it may be adequate to simply employ mechanical vibration or agitation in the fully degassed tank 24 such as through well-known mechanical devices in order to dissolve all of the residual air bubbles remaining in the liquid or water and in the holes and allow them to discharge through the drain 44.".

In contrast, the present Application discloses:

> (a) (at paragraph [0013]) "Inadequate electrolyte wetting problems are particularly problematic in relatively wide, but very deep openings. In particular, wetting is difficult inside openings with depth in the range of about 5-100μm and width in the range of about 5-200μm. Such openings are frequently used in 3-D wafer packaging (for contacts through the wafer), in chip-scale packaging (CSP), wafer-scale packaging (WSP), TFH, MEMS, and systems on chip (SOC). They are prone to insufficient or inadequate electrolyte wetting. For example, vias of such dimensions in 3-D packaging may require several hours of immersion in the electrolyte, for its complete penetration into the vias to wet and plate the lower sidewalls and bottom of the vias. As the width of the openings decreases, capillary forces become stronger, thus improving the wetting. As a result, narrower openings wet better and faster than wider openings of the same depth. For this reason, wetting problems are less prevalent in submicron openings, used in VLSI and ULSI copper interconnects (having width of about 0.1-0.5μm and depth of about 0.5-1.5μm), than in the

much wider (≥ 5μm) and deeper (≥ 10μm) openings encountered in packaging."; (b) (at paragraph [0055]) "In accordance with a preferred embodiment of the invention, ultrasonic vibrations or, more preferably megasonic vibrations, can be used in-situ in the plating electrolyte during both the activation-wetting step prior to the electrofilling, and during the JECD electrofilling step. The ultrasonic or megasonic vibrations can be utilized in conjunction with jets plating in order to further enhance the electrolyte agitation. This embodiment is particularly advantageous for fast, reliable, and smooth electrofilling of very deep (10-100μm) and relatively wide (5-100μm) openings, such as vias and grooves used in 3-D and high density packaging."

Referring to Applicant's Declaration, columns 2 (Via Width), 5 (Wetted Depth), and 6 (Wetted Depth Fraction) in Table I, and related Figures 2A-2D (Exhibit A) demonstrate Applicant's surprising and unexpected discovery that, as the width of the vias increased, the wetting problem became more prevalent. Or, in other words, the wider and lower aspect ratio openings had a more severe wetting problem than the narrower and higher aspect ratio openings.

Thus, as the Examiner can readily appreciate from the above, while Downes et al teaches that pre-wetting problems are mostly prevalent in higher aspect ratio holes or vias, and less significant (or prevalent) in lower aspect ratio holes or vias, the present Application, **surprisingly and unexpectedly**, identified a source of the wetting problem (due to insufficient capillary forces), which are more prevalent in the lower aspect ratio (wider) openings. Therefore, Applicant respectfully submits that, for at least this reason, Claim 1 is not obvious over Tzanavaras et al in view of Downes et al.

Hindsight

Since Tzanavaras et al clearly teaches away from a combination with Downes et al as described above, it becomes clear that the Examiner's proposed combination is based purely on improper hindsight, using the claims of the present invention as a roadmap. For at least these reasons, Applicant respectfully submits that Claim 1 is not obvious over Tzanavaras et al in view of Downes et al.

II. The Examiner rejected claims 2, 4-5, 7, 9, and 11 under 35 U.S.C. 103(a) as being unpatentable over Tzanavaras et al (US 5,421,987) in view of Downes, Jr et al (US 2002/0189637), as applied to claim 1 above, and further in view of Langner et al (US 4,834,842). The Examiner stated that:

The teachings of Tzanavaras et al, are described above.

None of these references expressly teach that the electrolyte plating bath included an inhibitor additive.

Langer et al (see abstract and col. 1, lines 18-34) a conventional additive for copper electroplating baths included inhibitors. The inhibitors were added to ensure a uniform deposit.

Therefore, it would have been obvious to one of ordinary skill in the art to have added an inhibitor as taught by Langer et al to the electrolyte of Tzanavaras et al because the inhibitor increased uniformity of the electroplated metal.

Regarding claims 4 and 9, Tzanavaras et al teach immersion of the substrate into the liquid electrolyte.

Regarding claims 5 and 11, Tzanavaras et al teach performing all the steps in a single chamber.

Not obvious: Applicant respectfully submits that, for the reasons discussed in Section **I** above, claim 1 is allowable over Tzanavaras et al in view of Downes et al and, since claims 2, and 4-5 depend from claim 1, they are also allowable over these references. The addition of Langner et al does not affect, whatsoever, the allowability of claim 1. Therefore, Applicant respectfully submits that claims 2, and 4-5 are allowable over Tzanavaras et al in view of Downes et al and further in view of Langner et al.

The Examiner also rejected independent Claim 7 (and its dependent claims 9 and 11) over Tzanavaras et al in view of Downes et al, for the same reasons of rejecting claim 1 over Tzanavaras et al in view of Downes et al. Applicant respectfully submits that, for at least the reasons discussed in Section I above for claim 1, independent claim 7 is allowable over Tzanavaras et al in view of Downes et al and, since claims 9 and 11 depend from claim 7, they are also allowable over these references. The addition of Langner et al does not affect, whatsoever, the allowability of claim 7. Therefore, Applicant respectfully submits that claims 7, 9, and 11 are allowable over Tzanavaras et al in view of Downes et al and further in view of Langner et al.

Furthermore, Applicant respectfully submits that Tzanavaras et al states (at column 2, lines 58-60): "*The present invention provides a new plating cell design which significantly improves both macro and micro-uniformities (thickness and composition)*". And (at column 3, lines 61-63): "*An object of this invention is to provide an electroplating cell for plating alloys having superior macro and micro-uniformities at a high rate of processing.*" Thus, contrary to the Examiner's assertion, Tzanavaras et al does not perceive any need for a further increased uniformity. Therefore, for at least this reason, claims 2, 4-5, 7, 9, and 11 are allowable, since the references themselves do not provide any motivation or suggestion to combine, and one of ordinary skill in the art would have no reason to combine them.

Furthermore, Applicant respectfully submits that claims 4-5, 7, 9, and 11, include further limitations that distinguish them over any combination of Tzanavaras et al, Downes et al, and Langner et al. Even if such a combination were proper (which Applicant strongly disputes), the combination of these three references does not show the further limitations of (a) that the activation or wetting solution is the same as the electrolyte used for the electroplating (claims 4, and 9), and (b) that the ultrasonic or megasonic vibrations is performed in the same chamber of the jets electroplating (claims 5 and 11). Applicant respectfully submits that the Examiner's assertion that: "*Regarding claims 4 and 9, Tzanavaras et al teach immersion of the substrate into the liquid electrolyte*" has no relevance to claims 4 and 9, since they require that the wetting or activation solution is the same as the electrolyte (used for the electroplating). Applicant respectfully submits that Tzanavaras does not disclose any wetting by ultrasonic or megasonic in the electrolyte. Similarly, Applicant respectfully submits that the Examiner's assertion that: "*Regarding claims 5 and 11, Tzanavaras et al teach performing all the steps in a single chamber*" is wrong, and has no relevance to claims 5 and 11, since Tzanavaras et al does not even mention an ultrasonic or megasonic step.

Furthermore, **Downes et al teaches away** from these limitations. See for example Downes et al (at paragraph [0040]): "*Upon completion of the prewetting process, which maybe a first step preceding an electroless copper plating or precleaning process sequence, the panels may be conveyed to a subsequent process tank (not shown) whereby typical tank-to-tank transfers may entail a period of time of 1 to 2 minutes.*" See also paragraphs [0022], [0028], [0031], and [0033] in Downes et al. In addition, claim 7 (as well as claims 9 and 11, which depend from it) includes the limitation that at least the field and the sidewalls surfaces of the opening comprise an exposed metallic surface. In contrast, Tzanavaras et al (see column 1, lines 7-12; and column 9, lines 58-62) discloses electroplating through a photoresist (insulating) mask, where only the bottom surface of the opening comprises an exposed metallic surface. Similarly, Downes et al discloses drilled holes or vias in printed circuit board (insulating) panels, which do not include exposed metallic surfaces on the sidewalls. Applicant respectfully submits that, for at least these reasons, claims 4-5, 7, 9, and 11 further distinguish, and are allowable, over any combination of Tzanavaras et al, Downes et al, and Langner at al.

Thus, Applicant respectfully submits that, for at least the reasons stated above, claims 2, 4-5, 7, 9, and 11 are allowable over Tzanavaras et al in view of Downes et al and in further view of Langner et al.

III. The Examiner rejected claims 3, 8, and 10 under 35 U.S.C. 103(a) as being unpatentable over Tzanavaras et al (US 5,421,987) in view of Downes, Jr et al (US 2002/0189637) and Langner et al (US 4,834,842) as applied to claims 2 and 7 above, and further in view of Hymes et al (US 6,423,200). The Examiner stated that:

> Tzanavaras et al fails to teach performing a preliminary activating treatment followed by wetting in the electrolyte.
>
> Hymes et al teach (see Figure 3A and col. 5, lines 32-56) that intermediate of a seed layer formation step and a copper electroplating step, an activation step is performed by etching the surface oxides existing on the copper seed layer to activate the seed layer to enhance electroplating process.
>
> Therefore, it would have been obvious to one of ordinary skill in the art to have performed an activation step as taught by Hymes et al in an activation solution different from the electrolyte in order to remove surface oxides from the copper seed layer. In view of the teachings of Downes, Jr et al, it would have been obvious to one of ordinary skill in the art to have applied ultrasonic vibrations during this activation treatment in order to enhance wetting of the copper seed layer within small vias and holes on the substrate to ensure adequate oxide removal.
>
> Regarding claim 10, Hymes et al teach using a separate chamber (seed layer treatment module 204) for the activation treatment from the electroplating chamber (electroplating module 206).

Not obvious: Applicant respectfully submits that, for the reasons discussed above in Sections **I** and **II**, claims 2(1), and 7 are allowable over Tzanavaras et al in view of Downes et al and Langner et al. Claims 3, which depends from claim 2(1), and claims 8 and 10, which depend from claim 7, are also allowable over these references. The addition of Hymes et al does not affect, whatsoever, the allowability of claims 2(1) and 7. Therefore, Applicant respectfully submits that claims 3, 8, and 10 are allowable over Tzanavaras et al in view of Downes et al and Langner et al and further in view of Hymes et al.

IV. The Examiner rejected claims 6 and 12 under 35 U.S.C. 103(a) as being unpatentable over Tzanavaras et al (US 5,421,987) in view of Downes, Jr et al (US 2002/0189637) and Langner et al (US 4,834,842) as applied to claims 5 and 11 above, and further in view of Reynolds (US 5,904,827). The Examiner stated that:

> Tzanavaras et al fails to teach applying the ultrasonic vibrations during the electroplating treatment.
>
> Reynolds teaches (see abstract, figure 3 and related description) including an megasonic transducer (90-92) for agitating the electrolyte in a copper electroplating process.
>
> Therefore, it would have been obvious to one of ordinary skill in the art to have continued applying the ultrasonic vibrations to the substrate and electrolyte as taught by Reynolds to the method of Tzanavaras et al and Downes, Jr et al because the ultrasonic vibrations would have increased uniformity of the electroplating (see Reynolds at col. 8, lines 45-56).

Not obvious: Applicant respectfully submits that, for the reasons discussed above in Sections **I** and **II**, claims 5(1) and 11(7) are allowable over Tzanavaras et al in view of Downes et al and

Langner et al. Since claim 6 depends from claim 5(1), and claim 12 depends from claim 11(7), they are also allowable over these references. The addition of Reynolds does not affect, whatsoever, the allowability of claims 5(1) and 11(7). Therefore, Applicant respectfully submits that claims 6, and 12 are allowable over Tzanavaras et al in view of Downes et al and Langner et al and further in view of Reynolds.

Furthermore, Applicant respectfully submits that even if the combination of these four references were proper (which Applicant strongly disputes), claims 6 and 12 still distinguish over this combination because they incorporate further limitations which are not disclosed by any of the references or a combination thereof. Thus, claims 6 and 12 require that all the steps, including pre-wetting or activation by ultrasonic or megasonic, and the jets electroplating be carried out in the same electrolyte and in the same chamber. As pointed out in Section **II** above, **Downes et al teaches away** from these limitations because it teaches a separate pre-wetting solution (which is different from the electroless solution) than the electrolyte, and that the pre-wetting step is done in a separate chamber than the plating chamber. See for example Downes et al (at paragraph [0040]): "*Upon completion of the prewetting process, which maybe a first step preceding an electroless copper plating or precleaning process sequence, the panels may be conveyed to a subsequent process tank (not shown) whereby typical tank-to-tank transfers may entail a period of time of 1 to 2 minutes.*" See also paragraphs [0022], [0028], [0031], and [0033] in Downes et al. Therefore, the combination of these four references for rejecting claims 6 and 12 is once again improper. Applicant respectfully submits that, for the reasons stated above, claims 6 and 12 are allowable over Tzanavaras et al in view of Downes et al and Langner et al and further in view of Reynolds.

Summary: Applicant respectfully submits that for at least the reasons stated above, claims 1-12 are allowable over all cited arts, separately, or in any combination thereof. Applicant further respectfully submits that new claims 21-24 depend from allowable independent claim 1 and, therefore, are also allowable, and that new claims 25-28 depend from allowable independent claim 7 and, therefore, are also allowable. Thus, Applicant respectfully submits that all claims 1-12, and 21-28 are allowable.

Respectfully submitted,

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By _____
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